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ABSTRACT

One hundred and sixty first grade boys and girls of normal intelligence were tested for ability to conserve multiple space relaticns. The criterion task apparatus was a wooden T with a model of schoolhouse attached and centered above the point of contact of the horizontal and vertical axis. The T had a track running the length of both its axes along which a small car could be manually directed. The child was asked to reproduce the space relations represented by the examiner's configuration by directing the car and/or rotating the T. An analysis of task-related errors supported Piaget's notion of representational space and the importance of particular field configurations. A figure's relative position was highly important to successful performance whereas absolute orientation was a secondary factor. More difficulty in reproducing space relaticns was experienced by the children on a 180 degree transformed field than in 90 degree right and 90 degree left rotations. An explanation for the manner in which reversals of symmetrical figures may occur was also presented. Results suggest that the ability to form and retain a flexible and reversible memory image may be cf paramount importance in the acquisition of a horizontal-vertical system. (Author/WY)

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# CHILDREN'S CONSERVATION OF MULTIPLE SPACE RELATIONS: [1]

## EFFECTS OF PERCEPTION AND REPRESENTATION

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There is general agreement that distortions in spatial relations show up in inability to orient on maps and diagrams, reading reversals, and rotations or dislocations of parts in form reproduction tests (De Hirsh, 1957) but that these distortions are not indicative of organic pathology in young children (Faust & Faust, 1966). The underlying factors related to the persistence of spatial disabilities in some children of normal intelligence, many of whom are identified subsequently as having a major learning disability, have not been identified. Piaget and Inhelder (1967), however, have presented a theoretical frame of reference which could prove useful in the early identification and treatment of children who fail to develop a horizontal-vertical coordinate system.

According to Piaget (1954) spatial representation insufficiencies resulting in learning disabilities are relatively independent of general intellectual operations and chronological age. Furthermore, Piaget distinguishes between representational space (an aspect of cognitive growth) and perceptual space (immediately available stimuli external to the child). Representational or conceptual space requires a reversible, memory image and evidence for its successful operation is the ability to store and manipulate mentally figure orientations and directional

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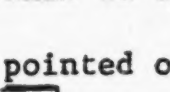
movements. Piaget's original approach to the study of the development of spatial representation was to present a child with a miniature model of a landscape and to require the child to reproduce the space relations of the landscape on a similar but rotated test field. The correct reproduction of the space relations represented by the experimenter's model under the 180° transformed condition is demonstration for conservation of multiple space relations.

On the other hand, variance on spatial tests due to field configuration (immediately perceivable) factors can result from differences in a discriminable figure's relative position or its absolute orientation with respect to the figure's recognizable axes. For instance, a U has a vertical axis of symmetry and a vertical main line axis, the latter of which is defined by the direction of the figure's predominant features. Relative position referes to the relationship of the figure to an adjacent point of critical interest or attention. As an example, copying a U to the figure's right would create an axis of separation (vertical) between the figure and the location of the copy. Copying a U above the figure would likewise create an axis of separation (horizontal) between figure and copy. Therefore relative position can be defined in terms of the juxtapositon (parallel or perpendicular) of an axis of separation with a figure's main-line and symmetrical axes.

In tasks that require the reproduction of a single figure there is evidence that error reversals of right and left (i.e., b & d) greatly outnumber up-down (i.e., p and b) reversals at all age levels (Emerson, 1931; Ghent and Berstein, 1961; Rudel and Teuber, 1963). It is also commonly held that figure orientation (axes vertical or horizontal), in contrast to relative position, causes the greatest amount

of spatial confusion. In contradistinction to this viewpoint, Huttenlocher (1967) found that the difficulty of copying a single symmetrical figure also varied with its position relative to the adjacent focus of attention; reproductions of a figure around its axis of symmetry were easier than other reproductions. Huttenlocher pointed out that if figures were presented as  and as the horizontally (latter pair) oriented figures were actually easier to discriminate.

Piaget (1954) has pointed out that variance can be readily attributed to perceptual factors as well as to the effects of representational processes. However, aside from the efforts of Feinberg and Laycock (1964), Kershner (in press), and Smock and Cox (1969), there has been a paucity of systematic attention given to assessing Piaget's position on the central importance of the reversibility of memory images or in identifying the contingencies in the perceptual field that might be related to the child's successful conservation.

The purpose of the study was to investigate the relative frequency of task-related, field configuration errors in order to assess the effects of field transformation, relative position and absolute orientation on children's ability to acquire a horizontal-vertical coordinate system.

## Procedure

### Subjects

The primary requirement was that the findings not be confounded with wide differences in sex, age, intelligence or social class influences. The subjects who participated in the study were 160 Grade-one

children, 80 males and 80 females, ages six and seven, of normal intelligence ( $\overline{X}$ = 115 ), who were selected from regular classes in two schools situated in upper middle class areas of Metropolitan Toronto, Ontario, Canada.

Intelligence test data were obtained from available school records and only children within the 98 to 130 I.Q. range were included in the study. The Dominion Tests (1956), a group test, had been administered earlier in the school term. For purposes of the present study, the I.Q. scores were used to eliminate extreme variations from the mean and to insure the relative within-sample homogeniety of the children in intellectual functioning.

The Conservation Test

The criterion test apparatus (see Figure 1) was developed during pilot work (Kershner, 1969) and is a wooden (T) that can be made to rotate 360° about its central axis at the point of horizontal and vertical intersection.

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Figure I here

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Elementary school children can work comfortably with it in either a sitting or standing position. Attached to and centered above the point of contact of the horizontal and vertical axes is a wooden figure (model schoolhouse) that is shaped like a ⌊⌋ and can be rotated 360° about its polar axis. The (T) has a track running the length of both of its axes along which a small model car can be manually directed. The figure is 3" high with a flat, bright red roof. The car is 2" high and is also colored bright red. The apparatus was set up in a vertical position so

that the child faced the dark green (T) while seated. To further minimize the effects of extraneous perceptual cues, a white, wrap-around 7 foot screen was placed behind the (T) and extended around the child covering the child's range of vision when seated in a forward position. Under the experimenter's manual control, the apparatus can be presented in four different (T) rotational transformations (upright, 90° right, 90° left, inverted 180°). The car can be moved through the vertical axis of the (T) to the choice point represented by the intersection of axes where it can be pushed past the school house in one of two directions. The school house also can be turned into right-left or up-down orientations.

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Figure 2 here

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Four field configurations were created (see figure 2) each of which was presented to the child: aligned, left-right, aligned, up-down; mirror, left-right; and mirror, up-down. In the aligned relative positions movement of the car to one side of the figure directs attention to that side thus producing an axis of separation that is perpendicular to the movement and <u>parallel to the figure's axis of symmetry</u>. In configurations where there is an axis of separation parallel to the axis of symmetry, the aligned image produced (if the figure is rotated 180° about its axis of symmetry) is identical and should facilitate correct reproduction. Similarly, in the mirror relative positions the axis of separation produced by juxtaposing the car to one side of the figure forms an axis of separation that is perpendicular to the movement but in this case <u>also perpendicular to</u>

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the figure's axis of symmetry. In configurations where there is an axis of separation perpendicular to the axis of symmetry, rotation of the figure about the axis of separation produces a different figure, which should induce confusion. Therefore, the one position is referred to as mirror image relative position where a rotation about the axis of separation should create an error, and the other as aligned relative position where rotation about the axis of symmetry should not interfere with its correct reproduction.

Following the presentation of each field configuration condition, the child was taken to an adjacent room and tested on a similar apparatus for his ability to reproduce the space relations represented by the experimenter's configuration. In the testing phase S was instructed to first orient the school and then to manually direct the car correctly past the school. In addition, each field configuration was assessed in four different rotational positions of the (T). (copy, $90^{\circ}$ right, $90^{\circ}$ left, inverted $180^{\circ}$ ). After the scores for one field configuration were obtained, S was returned to the original room and exposed to a second field configuration. In this manner, each S was exposed to the four field configurations and tested for his ability to reproduce each one under four different (T) transformations. Administration of

the criterion task was balanced for the sequence of exposure conditions and for the sequence of rotational positions to control for a subject by order effect. The child was given one point for each correct reproduction of the schoolhouse's orientation and one point for each correct reproduction of the car's directional movement. Thus, the criterion task yielded 32 total possible points per testing session.

Hypotheses

Hypothesis 1. There are more errors due to a figure's relative position than due to its absolute plane of orientation.

Hypothesis 2. There are more mirror-image relative position errors than aligned-image relative position errors.

Hypothesis 3. There are more horizontal absolute figure orientation errors than vertical absolute figure orientation errors.

Hypothesis 4. There are more errors in the 180° inversion test rotational position and in the 90° right and 90° left transformations in comparison to the copy position.

## Results

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Tables 1 and 2

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Table 1 is a breakdown of the relative frequency of errors. Table 2 indicates the relative difficulty of the particular field configurations of theoretical interest. When the figures were in mirror positions there were 263 errors in the horizontal plane and 259 in the vertical plane, whereas the aligned horizontal and aligned vertical planes resulted in 92 and 143 errors respectively. It is obvious, in light of the small differences between the horizontally

and vertically oriented figures, that a figure's relative position in respect to its axis of symmetry and axis of separation is a highly significant factor in its correct reproduction, thus supporting the first hypothesis.

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Tables 3 and 4 here

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An analysis of variance for four repeated measures on the same children presented in Table 3 indicates that there was a significant difference in the comparative difficulty of the rotated (T) positions. Employing Scheffé's (1959) multiple comparison test to the differences between pairs of means indicates that there were more errors significantly in the field transformations than in the copy position. The most errors were found in the 180° inversion and there were no differences between the two 90° rotations (see Table 4). It is apparent that reversed and rotated field configurations cause more difficulty than nontransformed ones, thus supporting the 4th prediction. Since there were more errors due to the mirror-image relative position the second hypothesis is also accepted. In further support of the primacy of relative position over absolute orientation is the small discrepancy in errors between the horizontally and vertically oriented figures. The third hypothesis therefore cannot be accepted.

## Discussion

The four field configurations of theoretical interest were assessed. The findings support the influence of task-related perceptual factors in conserving complex spatial relations but also highlight the predominant nature of the internal processing system which the child

brings to a spatial event.

The results revealed that in reproducing the dimensionalities of space, a figure's relative position in the perceptual field with respect to the relationship between its axes and the direction of eye scanning movements is a more important factor than the absolute plane of its orientation. Horizontally oriented figures were no more difficult to deal with on a representational level than vertically oriented figures thereby corroborating Piaget's contention that vertical and horizontal representation become operational simultaneously.

The disclosure of more errors in the mirror position than when the figure was in an aligned relative position may offer some insight into the manner in which figure reversals occur. It appears that if a figure has an axis of symmetry, eye-hand movements past the figure that are horizontal to the figure's axis of symmetry (perpendicular to the axis of separation) may induce a symmetrical 180° shift in the position of the figure--the figure moves through different planes as though hinged on the axis that is perpendicular to the direction of movement and produces a mirror image of the original. On the other hand reproductions around a figure's axis of symmetry are the easiest reproductions.

In both cases, in terms of the conservation test, the figure was reversed in the direction of, and with, the car's movement past the school house.

Perhaps of most significance to the early diagnosis and remediation of spatial disabilities is the finding that successful operation on a reversed field signified the highest development of the child's spatial schemata which also offers support for Piaget's reversibility criterion.

The 180° inversion was most difficult, followed by the 90° right and left transformations. All transformed field conditions were significantly more difficult than reproducing space relations on a copy. The results suggest that the ability to form and retain a flexible and reversible memory image may be of paramount importance in the acquisition of a horizontal-vertical system.

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## Footnotes

[1]The study was performed pursuant to a contract with the Valentine-Kline Foundation under the provisions of the Research Support Program and was also assisted by the Ontario Institute for Studies in Education, Toronto, Ontario, Canada.

TABLE 1

CATEGORIZATION OF ERRORS

| | Type | x | s |
|---|---|---|---|
| A | mirror | 3.18 | 2.37 |
| | aligned | 1.48 | 2.12 |
| B | horizontal | 2.20 | 2.10 |
| | vertical | 2.48 | 2.38 |
| C | direction | 5.00 | 2.93 |
| | orientation | 4.97 | 3.72 |
| D | copy | 1.90 | 1.58 |
| | 90° right | 2.34 | 1.88 |
| | 90° left | 2.39 | 1.86 |
| | 180° inversion | 2.72 | 1.96 |

Note: A and B refer only to figure orientation errors. C compares directional response errors with figure orientation errors and D is a total error breakdown according to field transformations.

TABLE 2

FIELD CONFIGURATION ERRORS INFORMATION

| | mirror right-left | mirror up-down | aligned right-left | aligned up-down |
|---|---|---|---|---|
| Total number of errors | 263 | 259 | 92 | 143 |

TABLE 3

ANALYSIS OF VARIANCE FOR REPEATED MEASURES COMPARING THE ERRORS OF THE FOUR ROTATIONAL POSITIONS

| Source | df | ss | ms | F |
|---|---|---|---|---|
| Subjects | 159 | 1498.275 | 9.423 | |
| Treatments | 3 | 54.288 | 18.096 | 13.72* |
| Error (within subjects and residual | 477 | 629.212 | 1.319 | |
| Total | 639 | 2181.776 | | |

* $p = < .05$

TABLE 4

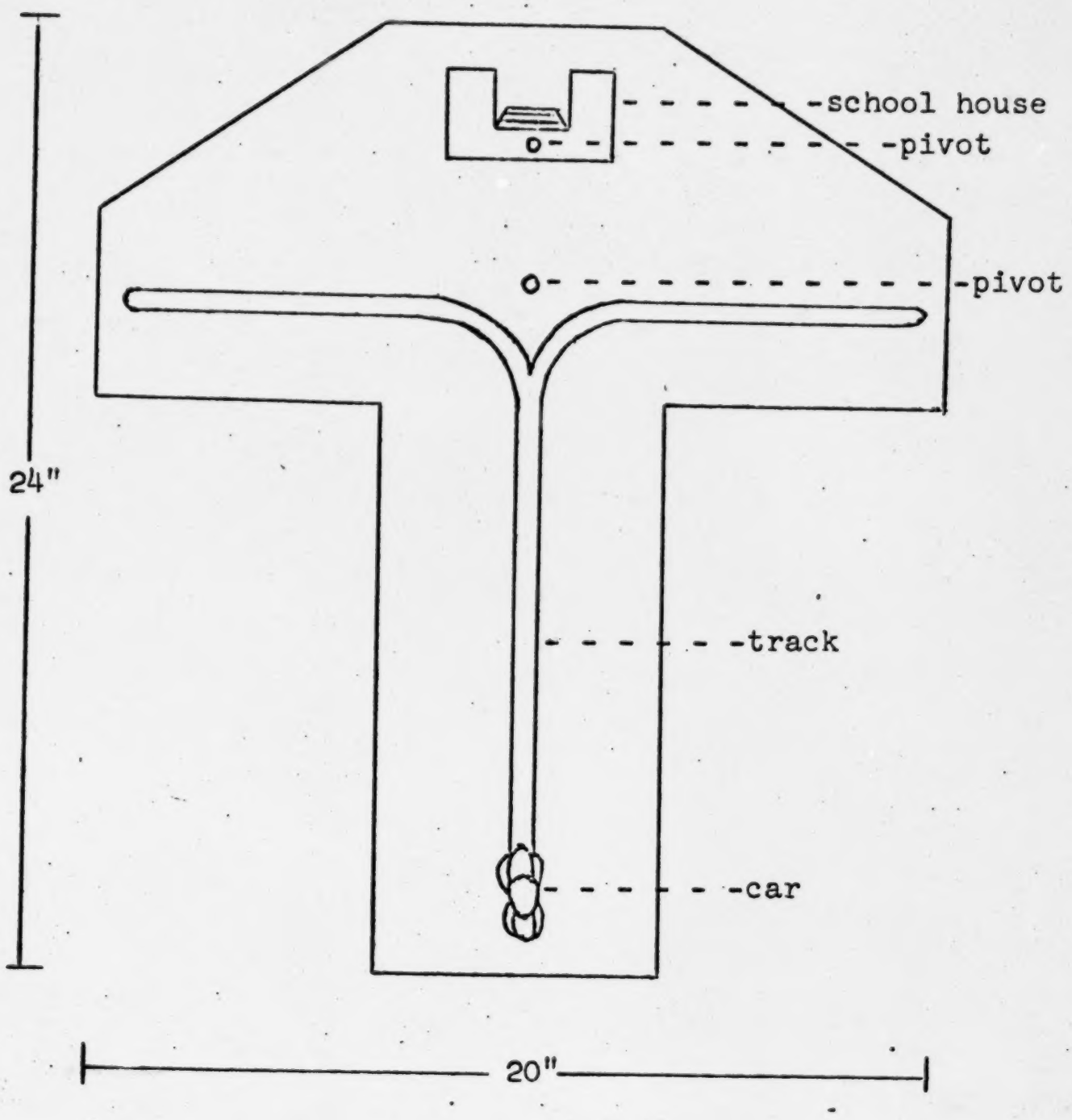
SCHEFFÉ COMPARISON OF ROTATION POSITION MEAN DIFFERENCES

| means \ means | | II 2.34 | III 2.39 | IV 2.72 |
|---|---|---|---|---|
| I | 1.90 | .44* | .49* | .82* |
| II | 2.34 | | .05 | .38* |
| III | 2.39 | | | .33 |

* $p = < .05$

FIGURE 1

CRITERION TASK APPARATUS[1]




[1] Details can be obtained from the author upon request.

FIGURE 2

FIELD CONFIGURATION CONDITIONS